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(पहला पुनरीक्षण)

Indian Standard

TESTING OF REFRIGERANT COMPRESSORS

(First Revision)

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Refrigeration and Airconditioning Sectional Committee, HMD 03

CONTENTS

ANNEXES

NATIONAL FOREWORD

This Indian Standard (First Revision) which is identical to ISO 917 : 1989 'Testing of refrigerant compressors' issued by the International Organization for Standardization (ISO), was adopted by the Bureau of Indian Standards on the recommendation of the Refrigeration and Airconditioning Sectional Committee (HMD 03) and approval of the Heavy Mechanical Engineering Division Council.

This standard was first issued in 1969 as 'Code of practice and measurement procedures for testing refrigerant compressors' and assistance was taken from draft ISO Recommendation 917 : 1968 'The testing of refrigerant compressors'. Consequent upon the revision of ISO standard as ISO 917 : 1989, this standard has been revised to bring it in line with international practices.

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Indian Standard
TESTING OF REFRIGERANT COMPRESSORS
(First Revision)

1 Scope and field of application

The provisions of this International Standard apply only to single-stage refrigerant compressors of the positive-displacement type. Selected test methods are described for the determination of the refrigerating capacity, the power, the isentropic efficiency and the coefficient of performance. These test methods provide results of sufficient accuracy to permit consideration of the suitability of a refrigerant compressor to operate satisfactorily under any set of basic test conditions required for a given refrigeration installation.

Attention is drawn in particular to a number of special precautions necessary to reduce testing losses to a minimum.

This International Standard applies only to tests carried out at the manufacturer's works, or wherever the necessary equipment for testing to the accuracy required can be made available. The types and calibration of measuring instruments and the accuracy of measurement are specified in annex A, which forms an integral part of this International Standard.

The test methods described may also be used as a guide for the testing of other types of refrigerant compressors.

NOTE — Tests on complete refrigeration installations are dealt with in ISO 916-1.

Annexes B and C, which provide additional information, do not form integral parts of this International Standard.

2 References

ISO 916-1, *Refrigeration systems — Test methods — Part 1 : Testing of systems for cooling liquids and gases using a positive displacement compressor.* [1)]

ISO 1662, *Refrigerating plants — Safety requirements.*

ISO 5167, *Measurement of fluid flow by means of orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full.*

ISO 5168, *Measurement of fluid flow — Estimation of uncertainty of a flow-rate measurement.*

3 Definitions

NOTE — A complete list of symbols and units used in the calculations, together with their definitions, is given in annex B.

3.1 refrigerating capacity of a refrigerant compressor Φ_0: Product of the mass flow rate of refrigerant through the compressor, as derived from the test, and the difference between the specific enthalpy of the refrigerant at the measuring point at the inlet of the compressor and the specific enthalpy of the saturated liquid at the temperature corresponding to the test discharge pressure at the measuring point at the outlet of the compressor.

3.2 volumetric efficiency, η_V: Ratio of the actual volume rate of flow at suction conditions, measured at the position specified in 4.3.2, to the displacement of the compressor.

3.3 power input, P: Power at the compressor shaft for an open compressor or power at the motor terminals for a hermetic motor compressor (or semi-hermetic motor compressor) together with the power absorbed by such ancillaries as are necessary to sustain the operation of the compressor, e.g. oil pump.

3.4 isentropic efficiency, η_i: Ratio of the product of the actual mass flow and the change in isentropic enthalpy across the compressor to the power input.

3.5 coefficient of performance, ε: Ratio of the refrigerating capacity to the power input.

NOTE — It should be made clear in the test resport whether the power input referred to is that measured at the compressor shaft or that at the motor terminals.

1) At present at the stage of draft.

Section one : Determination of refrigerating capacity and of volumetric efficiency

4 General procedure

4.1 Method of determination of refrigerating capacity and volumetric efficiency

The determination of the refrigerating capacity of a compressor comprises

a) the evaluation of the mass flow rate of the refrigerant, obtained for each test method used by means of an apparatus which is inserted in the outer part of the test circuit, between the outlet and the inlet of the compressor, as described in clauses 8 to 15, and

b) the determination from recognized tables, of the thermodynamic properties of the refrigerant, of the specific enthalpy of the refrigerant in the saturated-liquid state at the compressor discharge pressure and its specific enthalpy at the compressor suction pressure and temperature.

The volumetric efficiency is determined using the equation given in 6.7.2.

During the test, the refrigerant compressor should be furnished with all auxiliary equipment and accessories necessary for its satisfactory operation in normal use.

4.2 Tests

All tests shall comprise two test methods, a test X and a test Y, which shall be carried out simultaneously.

4.2.1 Test Y shall, wherever possible, be a different type of test than test X, so that its results are obtained independently from those of test X.

4.2.2 The values of the estimated errors for the refrigerating capacity shall be calculated for test X ($s\Phi_{0X}$) and for the selected test Y ($s\Phi_{0Y}$) (see annex C).

4.2.3 Specifications for test X and test Y and for their possible combinations are given in clause 7.

4.2.4 The results of test X and test Y for the refrigerating capacity shall be accepted provided that they correlate within $\pm$ 4 % (see annex C).

4.2.5 For results valid in accordance with 4.2.4, the refrigerating capacity and the volumetric efficiency shall be taken as the mean of the test X and test Y results.

The values of the estimated errors (sf_X and sf_Y) for test X and test Y, calculated as described in 4.2.2 and annex C, shall be used to determine the total estimated error (to one significant figure) for the valid result using the formula $[(sf_X^2 + sf_Y^2)/2]^{1/2}$.

4.3 General rules

In order to ensure that the results obtained are within the required limits of accuracy, it is essential to observe the following rules, and the instructions given in the note to 4.3.4 should be taken into account.

4.3.1 All instruments and auxiliary measuring apparatus shall be correctly located in relation to the compressor inlet and outlet, and shall be calibrated against master instruments of certified accuracy and adjusted if necessary to give readings within the limits of accuracy prescribed in annex A.

4.3.2 The pressure and temperature at the suction inlet to the compressor shall be measured at the same point which shall be located on a straight run of pipeline, at a distance of (or as close as possible to) eight times the pipe diameter, ahead of the point of entry or of the stop valve, if one is fitted.

The diameter of the pipe shall be consistent with that of the flange on the compressor for a length of at least sixteen times the pipe diameter.

4.3.3 The pressure and temperature at the discharge outlet of the compressor shall be measured at the same point which shall be located on a straight run of pipeline, at a distance not less than eight times the pipe diameter after the point of outlet or the stop valve, if one is fitted.

The diameter of the pipe shall be consistent with that of the flange on the compressor for a length of at least sixteen times the pipe diameter.

4.3.4 The correct refrigerant and lubricating oil charges shall be present in the circulation system. Efficient oil separators shall be fitted in the discharge line of the compressor unless it is shown by measurement that the oil pumping rate is less than 1,5 % of the refrigerant mass flow rate. If a separator is used, arrangements shall be made to return the separated oil direct to the compressor lubricating system.

If the compressor is designed for use on a normal oil returning circuit, the oil from the separator shall be returned to the suction line between the measuring apparatus and the compressor suction connection.

No refrigerant shall be added during the test, and no oil shall be added to enclosed crank cases which communicate with the refrigerant circuit.

During the whole of the test run, the circuit shall contain only the refrigerant and the lubricating oil in such conditions of purity that normal operation in the continuous running of the compressor will be assured and the precision of the test measurements will not be affected within the agreed tolerances.

NOTE — The complete elimination of liquid refrigerant and lubricating oil would be difficult to achieve. However, the error arising from these factors at the inlet of the compressor can generally be reduced to such an extent as to be negligible by

a) ensuring that the refrigerant vapour is sufficiently superheated at the inlet to the compressor (for this purpose a suction superheater may be required, and any heat supplied to it from an external source should be duly recorded), and

b) providing an efficient oil separator on the discharge line of the compressor.

In general, a correction for the effect of the lubricating oil is not necessary if the oil content of the oil-liquid refrigerant mixture is such as to cause an error not exceeding 1,5 % of the refrigerating capacity.

4.3.5 The system shall be tested for freedom from leaks of refrigerant and oil. The absence of non-condensable gases shall be confirmed by appropriate means.

4.3.6 The system shall be protected against abnormal air currents.

4.4 Test period

4.4.1 The tests specified refer exclusively to a refrigerant compressor operating continuously under conditions such that, for a specified period, fluctuations in all the factors likely to affect the results of a test remain between the limits prescribed and show no definite tendency to move outside these limits.

These conditions are termed steady working conditions.

4.4.2 After the compressor has been started, adjustments shall be made during a preliminary run until the measurements required for the test are within the allowable limits of variation.

4.4.3 Once steady working conditions having been reached, the readings for the test period shall be taken at equal time intervals not exceeding 20 min for a period of at least 1 h, during which at least four readings shall be taken.

If recording instruments are used, their accuracies shall be comparable with those specified in annex A.

4.4.4 The arithmetic mean of the successive readings for each measurement is taken as the value of the measurement for the test.

4.4.5 All quantitative measurements shall be made at the beginning and end of each time interval to check uniformity of operation, the difference between the first and last measurement of the test period being taken as the value for the test.

5 Basic test conditions and deviations

The basic test conditions, under which the test is to be performed, which shall be specified for the testing of a refrigerant compressor are as follows :

a) the absolute pressure at the measuring points in the suction and discharge pipelines of the compressor;

b) the suction temperature at the measuring point in the suction pipeline of the compressor;

c) the speed of rotation of the compressor.

The pressure readings shall not deviate by more than ± 1 % from the basic test conditions throughout the test period.

The temperature readings shall not deviate by more than ± 3 °C from the basic test conditions throughout the test period.

The speed shall not deviate by more than ± 1 % from the basic test conditions throughout the test period; for hermetic motor compressors, the voltage shall be within ± 3 % and the frequency within ± 1 % of the nameplate values throughout the test period.

6 Basis of calculations

6.1 Source of thermodynamic properties

The source from which thermodynamic properties are taken shall be stated in the test report.

6.2 Specific enthalpy

Subject to the rules and precautions defined under 4.3, the specific enthalpy of the refrigerant liquid at the compressor discharge pressure, and that at the compressor suction pressure and temperature, are obtained from recognized tables of the thermodynamic properties of the refrigerant used. In the case of the specific enthalpy at the compressor suction pressure and temperature, a correction for the presence of entrained lubricating oil to the equations from which the specific enthalpy values are derived may be necessary.

6.3 Mass flow rate of refrigerant

The mass flow rate is determined by using tests X and Y which are selected (see clause 7) from the tests described in clauses 8 to 15.

6.4 Specific volume of the refrigerant

The actual test value V_{ga} of the specific volume of the refrigerant vapour at the compressor inlet shall not differ by more than 2 % from the value V_{gl} of the specific volume of the refrigerant vapour corresponding to the specified basic test conditions.

6.5 Compressor speed

The actual test value n_a of the compressor speed shall not differ from the basic test conditions by more than the deviations specified in clause 5.

6.6 Value of the measured mass flow rate

Subject to the conditions given in 6.4 and 6.5, the value of the measured mass flow rate $q_{m\mathrm{f}}$ shall be adjusted by multiplying it by the factor $(V_{\mathrm{ga}}/V_{\mathrm{gl}})(n/n_{\mathrm{a}})$ for open-type compressors and by the factor $(V_{\mathrm{ga}}/V_{\mathrm{gl}})(f/f_{\mathrm{a}})$ for hermetic motor compressors.

6.7 Basic equations

6.7.1 The refrigerating capacity as defined in 3.1 for open-type compressors is calculated using the following basic equation :

$$\Phi_0 = q_{m\mathrm{f}} \frac{V_{\mathrm{ga}}}{V_{\mathrm{gl}}} \frac{n}{n_{\mathrm{a}}} (h_{\mathrm{g1}} - h_{\mathrm{f1}})$$

For hermetic motor compressors, the correction factor n/n_{a} is replaced by f/f_{a}.

6.7.2 The volumetric efficiency η_V as defined in 3.2 is calculated using the following basic equation :

$$\eta_V = \frac{q_{m\mathrm{f}} V_{\mathrm{ga}}}{V_{\mathrm{sw}}}$$

NOTE — Within the limits specified in this International Standard, it is assumed that the volumetric efficiency is constant.

7 Test methods

7.1 General

As specified in 4.2, all tests shall comprise two test methods. For each test, the information specified in the test report (see clause 20) together with the additional information specified for each test method (see clauses 8 to 15) shall be measured during the test period (see 4.4). Nine different test methods may be used as follows.

NOTE — Test methods A, B, C, G and K measure the total mass flow of the refrigerant by the use of calorimeters.

Method A : secondary fluid calorimeter in suction line (see clause 8).

Method B : flooded system refrigerant calorimeter in suction line (see clause 9).

Method C : dry system refrigerant calorimeter in suction line (see clause 10).

A heat-insulated calorimeter is connected with the suction inlet of the compressor to act as the evaporator.

Method D1 : refrigerant vapour flowmeter in the suction line (see clause 11).

Method D2 : refrigerant vapour flowmeter in the discharge line (see clause 11).

NOTE — Methods D1 and D2 measure the total mass flow of the refrigerant in the gaseous state.

Method F : refrigerant liquid flowmeter (see clause 12).

NOTE — Method F measures the total mass or volume flow of the refrigerant in the liquid state.

Method G : water-cooled condenser method (see clause 13).

The water-cooled condenser in the actual installation is suitably insulated and equipped to act as a calorimeter.

Method J : refrigerant vapour cooling water (see clause 14).

NOTE — Method J measures the flow of a portion only of the liquid refrigerant obtained from a special condenser.

Method K : calorimeter in discharge line (see clause 15).

A heat-insulated calorimeter is installed in the discharge pipeline of the compressor to receive the total flow of refrigerant in the gaseous state.

7.2 Choice of test methods for test X and test Y

Any of the methods A, B, C, D1, D2, F, G and K may be used for test X.

Any of the methods described may be used for test Y with the following exceptions :

a) the method used for test X;

b) any methods measuring the same quantity as test X. For example, if the method for test X measures the gas flow at the discharge side of the compressor, other methods that measure the gas flow at the discharge side of the compressor shall not be used for test Y.

Preferably, the methods for tests X and Y shall be of basically different types. The table gives allowed and recommended combinations of methods for tests X and Y.

Table 1 — Combinations of tests X and Y

Method for test X	Method for test Y	
	Allowed	Recommended
A	D1, D2, F, G, K	F, G, K
B	D1, D2, F, G, K	F, G, K
C	D1, D2, F, G, K	F, G, K
D1	A, B, C, D2, F, G, J, K	F, G, J, K
D2	A, B, C, D1, F, J	F, J
F	A, B, C, D1, D2, J, K	D1, D2, J, K
G	A, B, C, D1, F, J	D1, J
K	A, B, C, D1, F, J	D1, J

8 Method A : Secondary fluid calorimeter

8.1 Description

The secondary fluid calorimeter (see figure 1) consists of a direct expansion coil or a set of coils in parallel serving as a primary evaporator. This evaporator is suspended in the upper part of a pressure-tight heat-insulated vessel. A heater is located in the base of this vessel, which is charged with a volatile secondary fluid so that the heater is well below the liquid surface. The refrigerant flow is controlled by either a manual or a constant-pressure expansion valve, which shall be located close to the calorimeter. The expansion valve and the refrigerant pipelines connecting it to the calorimeter may be insulated to minimize the heat gain.

The calorimeter shall be insulated in such a manner that the heat leakage does not exceed 5 % of the refrigerating capacity of the compressor.

Provision shall be made for measuring the temperature of the secondary fluid.

Provision shall be made in accordance with the requirements of ISO 1662 to ensure that the refrigerant pressure does not exceed the safety limit for the apparatus.

8.2 Calibration

The calorimeter shall be calibrated by using the following heat loss method.

8.2.1 Adjust the heat input to the secondary fluid to maintain a constant pressure at a value corresponding to a temperature of saturation approximately 15 °C above the ambient air temperature. Maintain the ambient air temperature constant to within ± 1 °C.

8.2.2 If the heater is operated continuously, maintain the heat input constant to within ± 1 % and measure the pressure of the secondary fluid at hourly intervals until four successive values of the corresponding temperature of saturation do not vary by more than ± 0,5 °C.

8.2.3 If the heater is operated intermittently, the control shall be such that the temperature of saturation corresponding to the secondary fluid pressure is maintained constant to within ± 0,5 °C and readings of the heat input are taken at hourly intervals until four successive readings do not vary by more than ± 4 %.

8.2.4 Calculate the heat leakage factor using the formula

$$F_1 = \frac{\Phi_h}{t_p - t_a}$$

8.3 Procedure

Adjust the suction pressure by means of the refrigerant expansion valve and the temperature of the refrigerant vapour entering the compressor by varying the heat input to the secondary fluid. Adjust the discharge pressure by varying the temperature and flow of the condensing medium, or by a pressure control device in the discharge line.

8.4 Requirements

8.4.1 If the heater is operated continuously, the fluctuation in heat input due to any cause during the test period shall not be such as to cause a variation of more than 1 % in the calculated compressor capacity.

8.4.2 If the heater is operated intermittently, the temperature of saturation corresponding to the secondary fluid pressure shall not vary by more than ± 0,6 °C.

8.5 Additional information

The following information shall be recorded :

a) the pressure of the refrigerant vapour at the evaporator outlet;

b) the temperature of the refrigerant vapour at the evaporator outlet;

c) the pressure of the refrigerant liquid entering the expansion valve;

d) the temperature of the refrigerant liquid entering the expansion valve;

e) the ambient temperature at the calorimeter;

f) the pressure of the secondary fluid;

g) the heat input to the secondary fluid.

8.6 Determination of refrigerating capacity

8.6.1 The mass flow rate of the refrigerant, as determined by this test, is given by the formula

$$q_{mf} = \frac{\Phi_i + F_1 (t_a - t_s)}{h_{g2} - h_{f2}}$$

8.6.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_0 = q_{mf} \frac{V_{ga}}{V_{gl}} (h_{g1} - h_{f1})$$

9 Method B : Flooded system refrigerant calorimeter

9.1 Description

The flooded system refrigerant calorimeter (see figure 2) consists of a pressure-tight evaporator vessel, or vessels in parallel, in which heat is applied directly to the refrigerant in respect of

which the compressor is being tested. The refrigerant flow is controlled by a manual or constant-pressure expansion valve, or a suitable level control device, which shall be located close to the calorimeter. The expansion valve and the refrigerant pipeline connecting it to the calorimeter may be insulated to minimize the heat gain.

The calorimeter shall be insulated in such a manner that the heat leakage does not exceed 5 % of the refrigerating capacity of the compressor.

Provision shall be made for measuring the temperature of the secondary fluid and for ensuring that the pressure does not exceed the safety limit for the apparatus.

Provision shall be made in accordance with the requirements of ISO 1662 to ensure that the refrigerant pressure does not exceed the safety limit for the apparatus.

9.2 Calibration

The calorimeter shall be calibrated by using the following heat loss method.

9.2.1 Fill the calorimeter with refrigerant liquid to its normal operating level and close the liquid and vapour outlet stop valves. Maintain the ambient temperature constant to within ± 1 °C and supply heat to maintain the refrigerant temperature approximately 15 °C above the ambient temperature. Where liquid is used for heating, maintain the inlet temperature constant to within ± 0,3 °C and control the flow so that the temperature drop is not less than 6 °C. Where electric heating is used, maintain the input constant to within ± 1 %.

9.2.2 After thermal equilibrium has been established, take readings for the following periods :

a) for liquid heating, at hourly intervals until four successive readings of both inlet and outlet temperatures, with constant rate flow, do not vary by more than ± 0,3 °C;

b) for electric heating, at hourly intervals until four successive values of the temperature of saturation of the refrigerant do not vary by more than ± 0,5 °C.

9.2.3 Determine the heat input to the calorimeter as follows :

a) for liquid heating,

$$\Phi_i = c\,(t_1 - t_2)\,q_{m_t}$$

b) for electric heating, Φ_i is given by the electrical power input to the heater.

9.2.4 Calculate the heat leakage factor from the following formula :

$$F_l = \frac{\Phi_i}{t_r - t_a}$$

9.3 Procedure

Adjust the suction pressure at the compressor by means of the refrigerant expansion valve and the inlet temperature to the compressor by varying the heat input. However, when a level control is used, adjust the suction pressure by means of the heat input to the evaporator, and the inlet temperature to the compressor by the heat input to a superheater. Adjust the discharge pressure by varying the temperature and flow of the condensing medium, or by a pressure control device in the discharge line.

Where liquid is used for heating, the inlet temperature shall be maintained constant to within ± 0,3 °C and the flow shall be controlled so that the temperature drop is not less than 6 °C. The flow rate of the liquid shall be maintained constant to within ± 1 %. Where electric heating is used, the input shall be maintained constant to within ± 1 %.

9.4 Requirements

9.4.1 If the heater is operated continuously, the fluctuation in heat input due to any cause during the test period shall not be such as to cause a variation of more than 1 % in the calculated compressor capacity.

9.4.2 If the heater is operated intermittently, the temperature of saturation corresponding to the secondary fluid pressure shall not vary by more than ± 0,6 °C.

9.5 Additional information

The following information shall be recorded :

a) the pressure of the refrigerant vapour at the evaporator outlet;

b) the temperature of the refrigerant vapour at the evaporator outlet;

c) the pressure of the refrigerant liquid entering the expansion valve;

d) the temperature of the refrigerant liquid entering the expansion valve;

e) the ambient temperature at the calorimeter;

f) the temperature of the heating liquid entering the calorimeter;

g) the temperature of the heating liquid leaving the calorimeter;

h) the mass flow rate of heating liquid circulated;

i) the electrical input to the calorimeter.

9.6 Determination of refrigerating capacity

9.6.1 The mass flow rate of the refrigerant, as determined by this test, is given by the formula

a) for liquid heating,

$$q_{m_f} = \frac{c\,(t_1 - t_2)\,q_{m_l} + F_l\,(t_a - t_r)}{h_{g2} - h_{f2}}$$

b) for electric heating,

$$q_{m_f} = \frac{\Phi_h + F_l\,(t_a - t_r)}{h_{g2} - h_{f2}}$$

9.6.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_0 = q_{m_f}\,\frac{V_{ga}}{V_{gl}}\,(h_{g1} - h_{f1})$$

10 Method C : Dry system refrigerant calorimeter

10.1 Description

The dry system refrigerant calorimeter (see figure 3) consists of an arrangement of refrigerant tubes or tubular vessels of suitable length and diameter to accomplish evaporation of the refrigerant circulated by the compressor. The external surface of the evaporator may be heated either by means of a liquid circulating in an outer jacket, which may be a concentric tube, or electrically. Alternatively, a similar means of heating may be used within the evaporator.

The refrigerant flow is controlled by either a manual or a constant-pressure expansion valve, which shall be located close to the calorimeter. The expansion valve and the refrigerant pipeline connecting it to the calorimeter may be insulated in order to minimize the heat gain.

The calorimeter shall be insulated in such a manner that the heat leakage does not exceed 5 % of the refrigerating capacity of the compressor.

If the means of heating is external to the evaporator surface, a sufficient number (not less than ten) of suitably spaced temperature measuring devices shall be provided to determine the mean surface temperature for heat leakage calculations.

Provision shall be made for measuring the temperature of the secondary fluid and for ensuring that the pressure does not exceed the safety limit for the apparatus.

Provision shall be made in accordance with the requirements of ISO 1662 to ensure that the refrigerant pressure does not exceed the safety limit for the apparatus.

10.2 Calibration

The calorimeter shall be calibrated by using the following heat loss method.

10.2.1 Maintain the ambient temperature constant to within ± 1 °C and supply heat to maintain the mean surface temperature approximately 15 °C above the ambient temperature. Where liquid is used for heating, maintain the inlet temperature constant to within ± 0,3 °C and control the flow so that the temperature drop is not less than 6 °C. Where electric heating is used, maintain the input constant to within ± 1 %.

10.2.2 After thermal equilibrium has been established, take readings for the following periods :

a) for liquid heating, at hourly intervals until four successive readings of both inlet and outlet temperatures, with constant rate flow, do not vary by more than ± 0,3 °C;

b) for electric heating, at hourly intervals until four successive values of the temperature of saturation of the refrigerant do not vary by more than ± 0,6 °C.

10.2.3 Determine the heat input to the calorimeter as follows :

a) for liquid heating,

$$\Phi_i = c\,(t_1 - t_2)\,q_{m_t}$$

b) for electric heating, Φ_i is given by the electrical power input to the heater.

10.2.4 Calculate the heat leakage factor from the formula

$$F_l = \frac{\Phi_i}{t_c - t_a}$$

10.3 Procedure

Adjust the suction pressure at the compressor by means of the refrigerant control and the inlet temperature to the compressor by varying the heat input. Adjust the discharge pressure by varying the temperature and flow of the condensing medium, or by a pressure control device in the discharge line.

Where liquid is used for heating, the inlet temperature shall be maintained constant to within ± 0,3 °C and the flow controlled so that the temperature fall is not less than 6 °C. The mass of liquid circulated shall be maintained constant to within ± 0,5 %. Where electric heating is used, the input shall be maintained constant to within ± 1 %.

10.4 Requirements

10.4.1 If the heater is operated continuously, the fluctuation in heat input due to any cause during the test period shall not be such as to cause a variation of more than 1 % in the calculated compressor capacity.

10.4.2 If the heater is operated intermittently, the temperature of saturation corresponding to the secondary fluid pressure shall not vary by more than ± 0,6 °C.

10.5 Additional information

The following information shall be recorded :

a) the pressure of the refrigerant vapour at the evaporator outlet;

b) the temperature of the refrigerant vapour at the evaporator outlet;

c) the pressure of the refrigerant liquid entering the expansion valve;

d) the temperature of the refrigerant liquid entering the expansion valve;

e) the ambient temperature at the calorimeter;

f) the temperature of the heating liquid entering the calorimeter;

g) the temperature of the heating liquid leaving the calorimeter;

h) the mass flow rate of heating liquid circulated;

i) the electrical input to the calorimeter;

j) the mean surface temperature of the calorimeter.

10.6 Determination of refrigerating capacity

10.6.1 The mass flow rate of the refrigerant, as determined by the test, is given by the formula

a) for liquid heating,

$$q_{m_\mathrm{f}} = \frac{c\,(t_1 - t_2)\,q_{m_\mathrm{l}} + F_\mathrm{l}\,(t_\mathrm{a} - t_\mathrm{c})}{h_\mathrm{g2} - h_\mathrm{f2}}$$

b) for electric heating,

$$q_{m_\mathrm{f}} = \frac{\Phi_\mathrm{h} + F_\mathrm{l}\,(t_\mathrm{a} - t_\mathrm{c})}{h_\mathrm{g2} - h_\mathrm{f2}}$$

10.6.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_0 = q_{m_\mathrm{f}} \frac{V_\mathrm{ga}}{V_\mathrm{gl}} (h_\mathrm{g1} - h_\mathrm{f1})$$

11 Methods D1 and D2 : Refrigerant vapour flowmeter

11.1 Description

The refrigerant vapour flowmeter is placed in the suction line (method D1) or in the discharge line (method D2) (see figure 4).

The necessary sampling points are installed to measure the pressure and temperature to enable calculation to be made of the specific mass of the refrigerant. The test set-up shall be such that the standard deviation of the final result (i.e. the mass flow rate of the refrigerant) does not exceed 2 %.

The refrigerant vapour flowmeter is installed in the suction or delivery pipeline of a closed circuit which consists of the refrigerant compressor, a means for reducing the refrigerant pressure from the discharge level to the suction level, a means of reducing excessive vapour superheat and a means for returning the conditioned vapour to the inlet (suction) of the compressor. The means for reducing the pressure may be either manually operated or controlled by the suction pressure. The means for removing the heat of compression may be provided by tapping sufficient refrigerant vapour from the high-pressure side of the circuit, liquefying it in a condenser and re-evaporating it in a heat exchanger with superheated refrigerant in the low-pressure side of the circuit, to ensure that the resulting superheated vapour is free from entrained droplets of liquid refrigerant.

11.1.1 The refrigerant mass flow rate q_{m_f} is measured at a point in the suction or delivery pipeline of the compressor where the full refrigerant flow takes place, and means shall be provided to ensure that the superheated vapour at this point is homogeneous and completely free from entrained droplets of liquid refrigerant.

Where pulsating flow occurs in the pipeline, sufficient means of damping shall be provided to reduce or eliminate the flow wave to the meter, for example by the insertion of a surge vessel (see figure 4).

11.1.2 As the calculations for the determination of the refrigerating capacity are based on the measurement of pure vapour, even a small quantity of oil present in the vapour would result in an inaccurate value for the gas flow through the meter and, therefore, for the refrigerating capacity of the compressor. The use of the refrigerant vapour flowmeter is therefore limited to circuits where the gas flow being measured contains less than 1,5 % oil. The oil content is the mass of oil per unit mass of liquid refrigerant-oil mixture (kilogram per kilogram).

11.2 Procedure

Adjust the suction pressure at the compressor by means of the refrigerant flow control device and the inlet temperature by varying the cooling effect. Adjust the discharge pressure by varying the temperature and flow of the condensing medium, or by using a pressure control device in the discharge line.

11.3 Additional information

The following information shall be recorded :

a) the temperature of the refrigerant vapour at the upstream side of the metering device;

b) the pressure of the refrigerant vapour at the upstream side of the metering device;

c) the pressure drop between the upstream and downstream side of the metering device.

11.4 Determination of refrigerating capacity

The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_0 = q_{m_f} \frac{V_{ga}}{V_{gl}} (h_{g1} - h_{f1})$$

12 Method F : Refrigerant liquid quantity using a flowmeter

12.1 Description

The refrigerant liquid meter (see figure 5) is either a quantity meter for recording the flow of refrigerant in units of volume or a flowmeter for indicating the instantaneous flow rate of the refrigerant.

12.1.1 The meter is connected to the liquid pipeline between the liquid receiver outlet and the expansion valve.

12.1.2 In order that the meter used may function properly under all conditions and that it may be protected from abuse and from the effects of an insufficient charge of refrigerant, additional apparatus is provided as follows :

a) a sub-cooler ahead of the meter to prevent vaporization of refrigerant in the meter;

b) sight glasses located immediately before the sub-cooler and just after the meter to enable a check to be made that vapour bubbles are not mixed with the refrigerant liquid;

c) a bypass valve and piping for bypassing the meter (the valve may be open, except when data are being recorded, provided that the valve and bypass circuit have a resistance approximately equal to that of the meter);

d) thermometers and wells, or alternatively thermocouples, for measuring the temperatures at which the refrigerant liquid enters the sub-cooler and the meter;

e) a pressure gauge connected to the outlet side of the meter.

12.2 Calibration

The meter shall be calibrated periodically at not less than three flow rates in the capacity range used.

12.3 Procedure

Start the operation of the system with the meter bypass valve open. After the specified conditions for the performance test have been established, close the bypass valve and check that the refrigerant liquid leaving the flowmeter has a sub-cooling of at least 3 °C.

Take readings concurrently with and at the same time intervals as those specified for the other test method.

Determine the proportion of oil present in the refrigerant.

12.4 Additional information

The following information shall be recorded :

a) the reading of the meter;

b) the pressure at the outlet of the meter;

c) the temperature of the liquid at the outlet of the meter.

12.5 Determination of refrigerating capacity

The refrigerating capacity, corrected for the oil content and adjusted to the specified basic test conditions, is given by the formula

$$\Phi_0 = \frac{q_V \cdot \varrho}{1 - x(1 - \mu\varrho)} \left[(1 - x)(h_{g1} - h_{f1}) - c_o x (t_f - t_g) \right] \frac{V_{ga}}{V_{gl}}$$

13 Method G : Water-cooled condenser

13.1 Description

The water-cooled condenser (see figure 6) which forms a part of the equipment used with the compressor being tested shall be equipped to act as a calorimeter by the provision of instruments for measuring temperatures, pressures and cooling water flow, within the limits of accuracy prescribed in annex A.

13.2 Calibration

The condenser shall be isolated from the refrigerant circuit, or a condenser of the same type and size shall be used.

13.2.1 Fill the condenser with refrigerant liquid to a suitable level and close the inlet and outlet stop valves. Connect the cooling water circuit to a supply of heated water capable of maintaining the refrigerant at a constant temperature of not less than 15 °C above the ambient temperature, but as near as possible to the expected saturation temperature.

Alternatively, the refrigerant may be heated electrically.

Maintain the ambient temperature constant to within ± 1 °C of any desired value not exceeding 43 °C. After thermal equilibrium has been established, take readings at hourly intervals until four successive values of the temperature of the refrigerant do not vary by more than ± 1 °C.

13.2.2 Calculate the heat leakage factor from the formula

$$F_l = \frac{\Phi_i}{t_r - t_a}$$

13.3 Procedure

Adjust the condenser pressure by varying the temperature and mass flow rate of the water supply to the condenser.

13.4 Additional information

The following information shall be recorded :

a) the pressure of the refrigerant vapour entering the condenser;

b) the temperature of the refrigerant vapour entering the condenser;

c) the pressure of the refrigerant liquid leaving the condenser;

d) the temperature of the refrigerant liquid leaving the condenser;

e) the temperature of the cooling water entering the condenser;

f) the temperature of the cooling water leaving the condenser;

g) the mass flow rate of the cooling water;

h) the ambient temperature at the condenser.

13.5 Determination of the refrigeration capacity

13.5.1 The mass flow rate of the refrigerant is given by the formula

$$q_{m_\mathrm{f}} = \frac{c\,(t_2 - t_1)\,q_{m_\mathrm{c}} + F_\mathrm{l}\,(t_\mathrm{r} - t_\mathrm{a})}{h_\mathrm{g3} - h_\mathrm{f3}}$$

13.5.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_0 = q_{m_\mathrm{f}}\,\frac{V_\mathrm{ga}}{V_\mathrm{gl}}\,(h_\mathrm{g1} - h_\mathrm{f1})$$

14 Method J : Refrigerant vapour cooling

14.1 Description

The total refrigerant flow is determined by condensing a portion of the vapour circulating at high pressure, measuring its quantity and then re-evaporating it at low pressure in a gas cooler to cool the remainder of the vapour circulated (see figure 7).

After correction for losses, the ratio of the condensed refrigerant to the uncondensed refrigerant is the inverse of the ratio of the change in specific enthalpy of the two streams mixing in the gas cooler.

14.1.1 The condenser is connected to the discharge pipeline of the compressor through a flow control valve that may be manually controlled or operated automatically in response to the discharge pressure. The condenser discharges liquid refrigerant into the flow-measuring apparatus, as described in method F, the outlet of which is connected to the inlet of the gas cooler, through a pressure-reducing valve operated either manually or automatically to maintain a predetermined suction pressure.

14.1.2 The gas cooler comprises a vessel into which the liquid refrigerant is injected and re-evaporated by mixing intimately with the uncondensed remainder of the vapour from the compressor discharge. The design shall be such that the outgoing vapour will not entrain droplets of refrigerant and is superheated by at least 8 °C.

The gas cooler shall be insulated in such a manner that the heat leakage is not greater than 5 % of the heat exchanged therein.

14.1.3 A liquid receiver shall be located at the outlet of the flowmeter. This will be so equipped with stop valves and bypass valves that it can be isolated from the liquid circuit or it can receive liquid from, or supply liquid to, the circuit.

14.2 Calibration

The gas cooler shall be calibrated according to the following procedure.

14.2.1 Fill the gas cooler with sufficient liquid refrigerant to ensure that, when both inlet and outlet stop valves are closed, it will not be wholly evaporated when the ambient temperature is maintained constant to within ± 1 °C and heat is supplied so that the temperature of the refrigerant is maintained approximately 15 °C above the ambient temperature.

After thermal equilibrium has been established, take readings at hourly intervals until four successive values of the temperature of saturation of the refrigerant do not vary by more than ± 1 °C.

14.2.2 Calculate the heat leakage factor from the formula

$$F_\mathrm{l} = \frac{\Phi_\mathrm{i}}{t_\mathrm{r} - t_\mathrm{a}}$$

14.3 Procedure

Adjust the regulating valve controlling the flow of the condensed refrigerant liquid to the gas cooler so that liquid is evaporated at the same rate as that at which it is condensed.

Control the condensing pressure using the valve between the discharge pipeline and the condenser and also by varying the temperature and rate of flow of the condensing medium. Adjust the suction pressure at the compressor and its superheat temperature using the valve at the inlet to the gas cooler, and by varying the mass flow rate of refrigerant by adding liquid to or withdrawing it from the liquid receiver.

In establishing the desired suction and discharge pressures and temperatures for the test, the liquid control valve is adjusted to maintain a constant flow.

14.4 Requirements

The fluctuation in the flow of the condensing refrigerant liquid during the test shall not be such as to cause a variation of more than 1 % in the calculated compressor capacity.

14.5 Additional information

The following information shall be recorded :

a) the pressure of the refrigerant vapour at the gas cooler outlet;

b) the temperature of the refrigerant vapour at the gas cooler outlet;

c) the pressure of the refrigerant liquid at the expansion valve;

d) the temperature of the refrigerant liquid at the expansion valve;

e) the pressure of the refrigerant vapour entering the gas cooler;

f) the temperature of the refrigerant vapour entering the gas cooler;

g) the pressure of the refrigerant vapour in the gas cooler;

h) the ambient temperature at the gas cooler;

i) the mass flow rate of the refrigerant liquid condensed.

14.6 Determination of refrigerating capacity

14.6.1 The total mass flow rate of the refrigerant, as determined by this test, is given by the formula

$$q_{m_t} = q_{m_l} \left[1 + \frac{(h_{g5} - h_{f2}) - F_l/q_{m_l}(t_a - t_r)}{(h_{g4} - h_{g5})} \right]$$

14.6.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_0 = q_{m_t} \frac{V_{ga}}{V_{gl}} (h_{g1} - h_{f1})$$

15 Method K : Calorimeter in compressor discharge line

15.1 Description

The apparatus for this method comprises the following items (see figure 8).

a) A heat exchanger of the calorimetric type, inserted in the discharge pipeline from the compressor to receive the total flow of refrigerant in the gaseous state.

The calorimeter vessel is supplied with a controlled circulation of a suitable liquid medium for the cooling (or heating[1]) of the gaseous refrigerant. In order to eliminate the possibility of any condensation of the refrigerant in the calorimeter vessel, the lower temperature of the circulated cooling medium shall be kept well above the temperature of condensation of the refrigerant corresponding to the discharge pressure from the compressor.

Alternatively, the gaseous refrigerant may be heated electrically.

The calorimeter shall be insulated so as to reduce the thermal losses to a minimum.

b) Apparatus for reducing the gaseous refrigerant issuing from the calorimeter to, as near as possible, the specified basic test conditions at the compressor inlet. Two arrangements, system A and system B, suitable for this purpose are shown in figure 8. A description of the use of arrangement A is given in 15.6.

15.2 Calibration

The calorimeter is calibrated by the heat loss method according to the following procedure.

15.2.1 Maintain the ambient temperature constant to within ± 1 °C and supply heat to maintain the mean surface temperature approximately 15 °C above the ambient temperature. Where liquid is used for heating, maintain the inlet temperature constant to within ± 0,3 °C and control the flow so that the temperature drop is not less than 6 °C. Where electric heating is used, maintain the input constant to within ± 1 %.

The mean surface temperature shall be taken as the average of the readings of at least 10 temperature-measuring devices suitably distributed on the external surface.

15.2.2 After thermal equilibrium has been established, take readings for the following periods :

a) for liquid heating, at hourly intervals until four successive readings of both inlet and outlet temperatures, with constant rate flow, do not vary by more than ± 0,3 °C;

b) for electric heating, at hourly intervals until four successive values of the temperature of the calorimeter do not vary by more than ± 0,6 °C.

1) The formula given in 15.5.1 is for cooling.

15.2.3 Determine the heat input to the calorimeter as follows :

a) for liquid heating,

$$\Phi_i = c\,(t_1 - t_2)\,q_{m_l}$$

b) for electric heating, Φ_i is given by the electrical power input to the heater.

15.2.4 Calculate the heat leakage factor from the formula

$$F_l = \frac{\Phi_i}{t_c - t_a}$$

15.3 Procedure

The procedure to be followed for system A is given in 15.6.2.

15.4 Additional information

The following information shall be recorded :

a) the pressure of the refrigerant vapour at the calorimeter inlet;

b) the temperature of the refrigerant vapour at the calorimeter inlet;

c) the pressure of the refrigerant vapour at the calorimeter outlet;

d) the temperature of the refrigerant vapour at the calorimeter outlet;

e) the ambient temperature near the calorimeter and the mean temperature of the surface of the calorimeter;

f) for liquid heating,

1) the temperature of liquid entering the calorimeter,

2) the temperature of liquid leaving the calorimeter,

3) the mass flow rate of the circulated liquid;

g) for electrical heating, the electrical power consumption at the calorimeter.

15.5 Determination of refrigerating capacity

15.5.1 The mass flow of the refrigerant, as determined by this test, is given by the formula

$$q_{m_f} = \frac{q_{m_l} c\,(t_2 - t_1) + F_l\,(t_c - t_a)}{(h_{g6} - h_{g7})}$$

15.5.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_0 = q_{m_f} \frac{V_{ga}}{V_{gl}} (h_{g1} - h_{f1})$$

15.6 Example of completion of circuit

15.6.1 Description

System A (see figure 8) consists of the following :

a) a surface condenser, into which a controlled amount of the gaseous refrigerant, after passing the calorimeter, is diverted and condensed;

b) an expansion valve, which may be of the constant-pressure automatic type, to reduce the pressure of the remaining refrigerant to that required at the compressor suction;

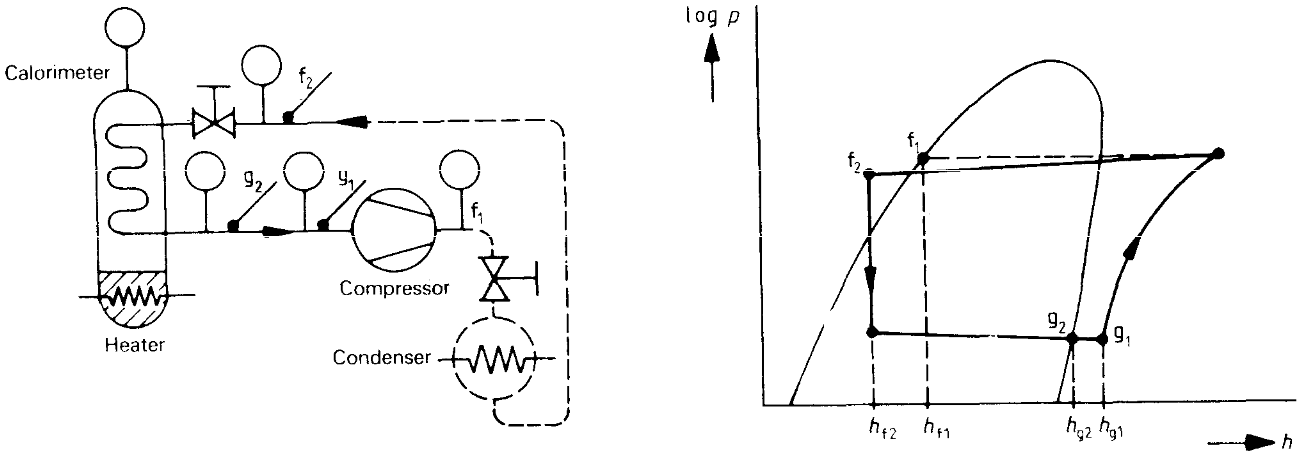
c) a gas cooler, to reduce the superheat of the expanded refrigerant to that required at the compressor suction.

The reduction in superheat is achieved by injecting into the gas cooler the volume of refrigerant condensed in the condenser and then by evaporating it. This volume is adjusted by using a suitable liquid throttle valve in the condensate discharge line to the cooler.

15.6.2 Procedure

Adjust the suction pressure at the compressor inlet by means of the expansion valve which is located between the compressor discharge pipe and the vapour inlet to the gas cooler.

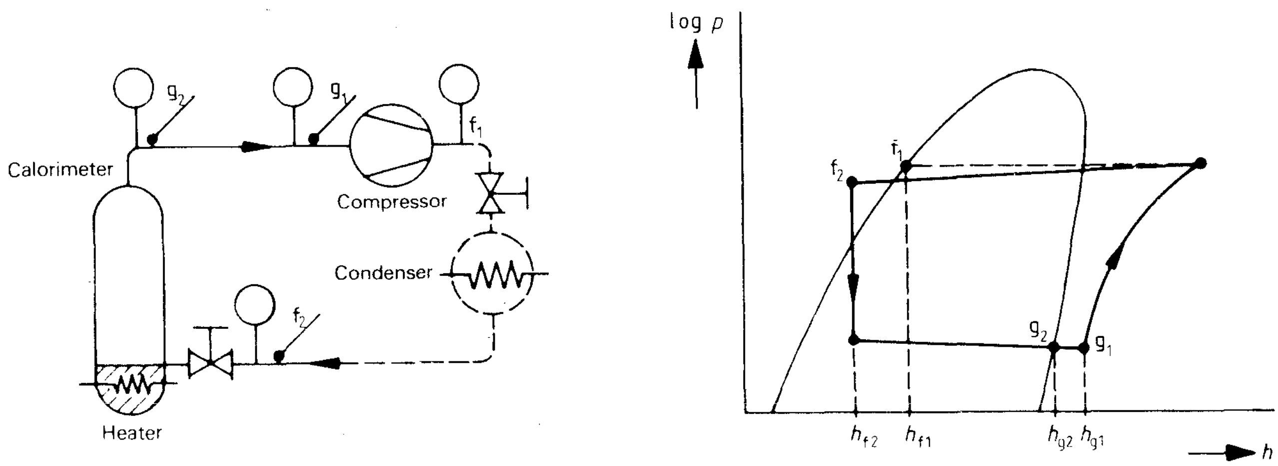
Adjust the condenser pressure by means of the valve which is located between the compressor discharge pipe and the condenser, and also by varying the temperature and mass flow rate of the water supply to the condenser.



a) **Circuit diagram**

b) **Log p versus h diagram**

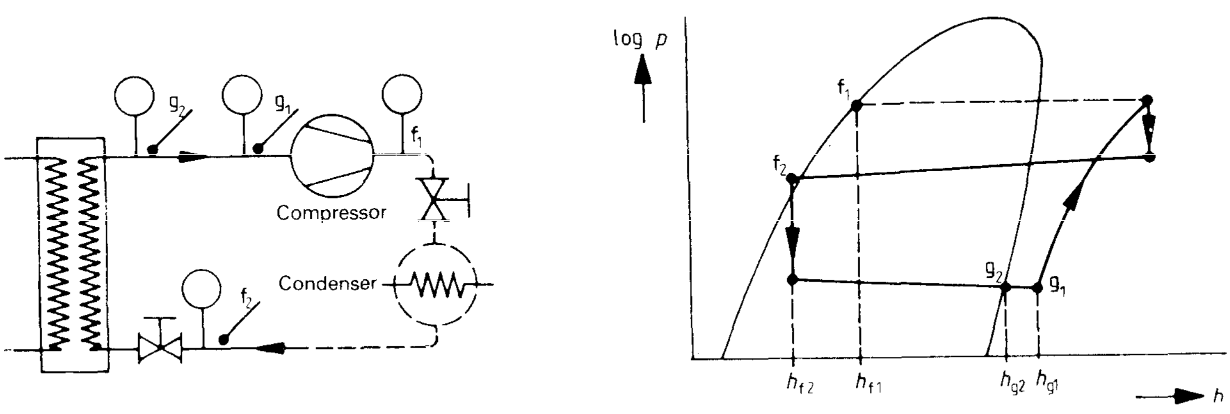
Figure 1 — Method A



a) **Circuit diagram**

b) **Log p versus h diagram**

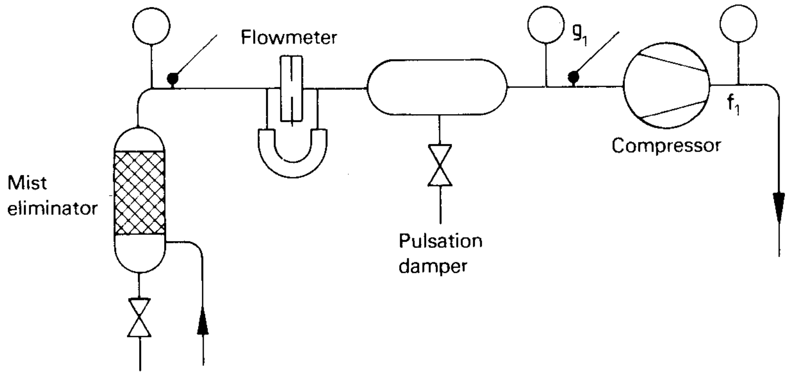
Figure 2 — Method B



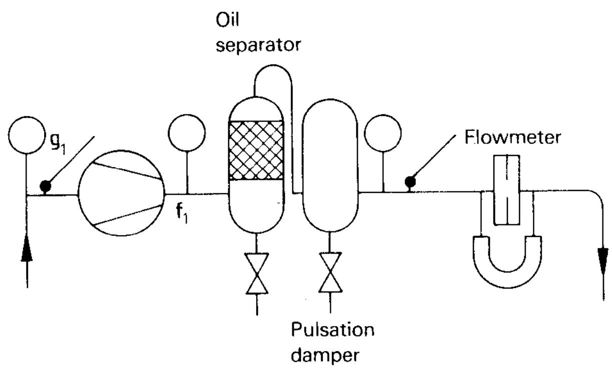
a) **Circuit diagram**

b) **Log p versus h diagram**

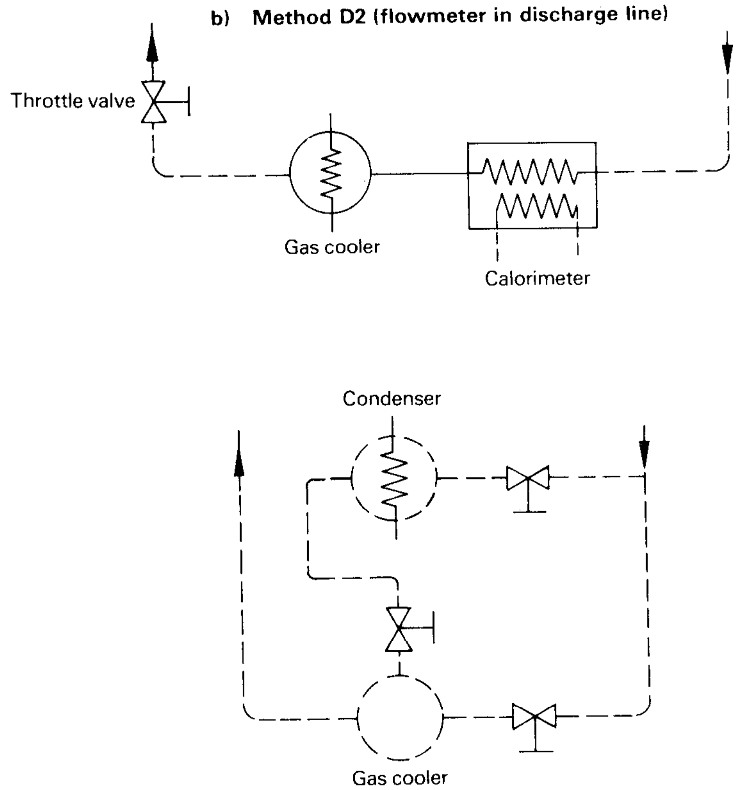
Figure 3 — Method C



a) **Method D1 (flowmeter in suction line)**

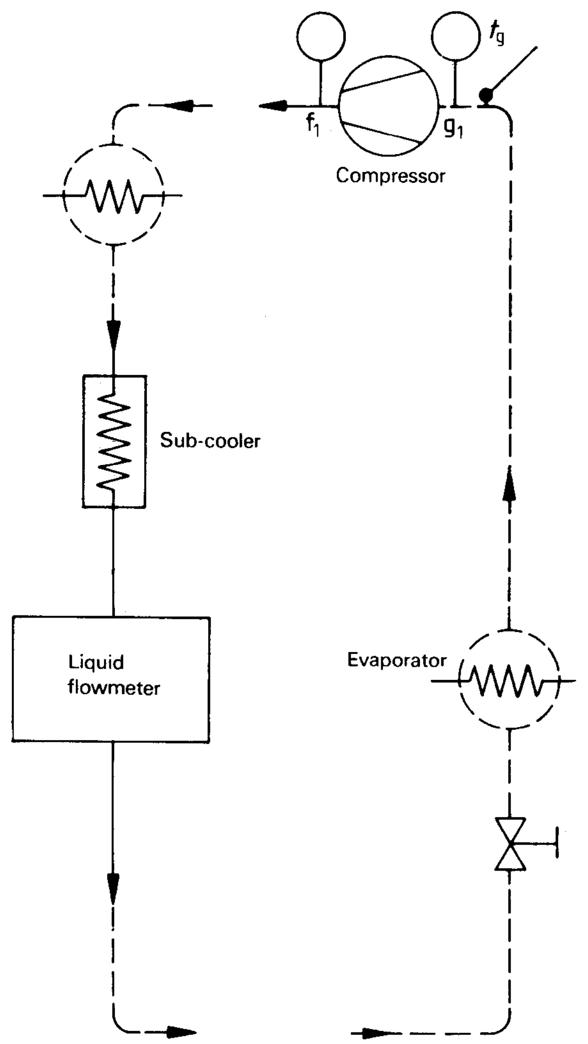


b) **Method D2 (flowmeter in discharge line)**

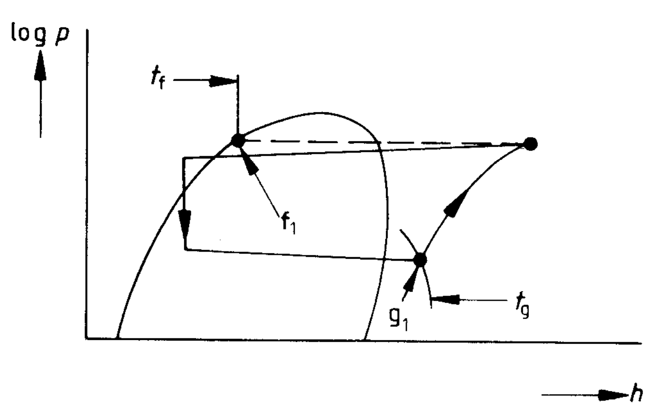


c) **Two examples showing the completion of the circuit**

Figure 4 — Circuit diagrams for methods D1 and D2

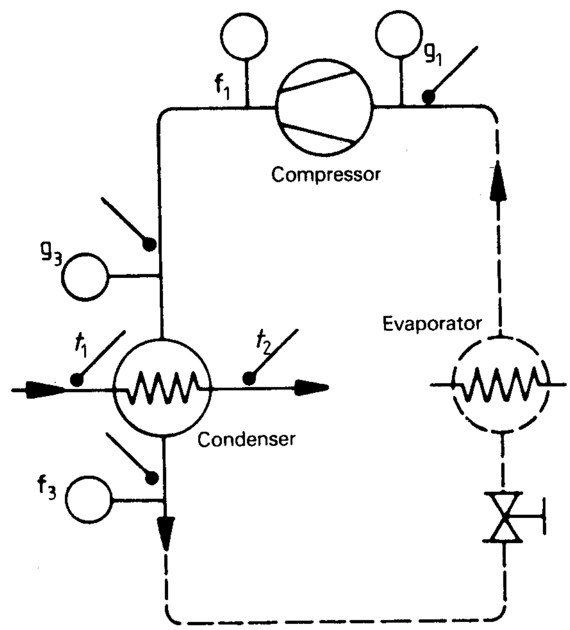


a) Circuit diagram

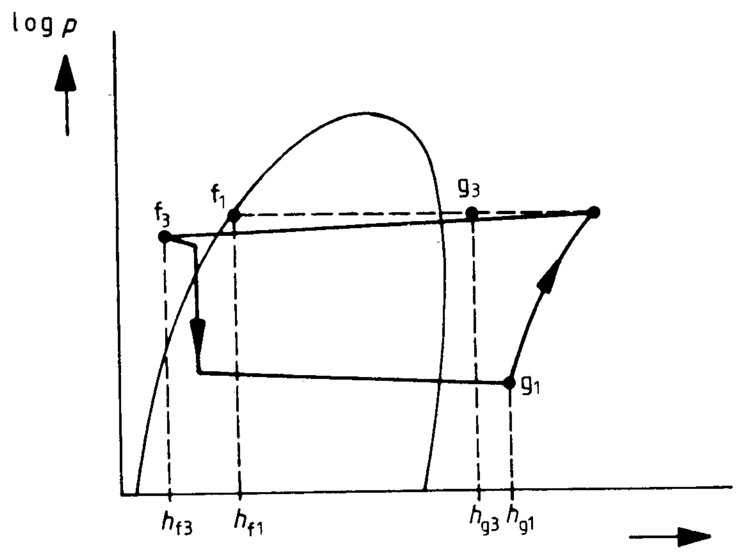


b) Log p versus h diagram

Figure 5 — Method F

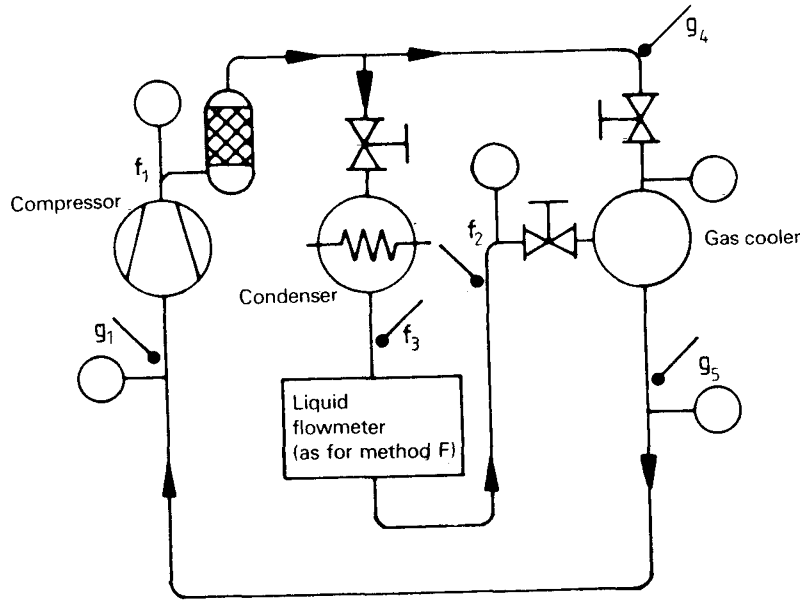


a) Circuit diagram

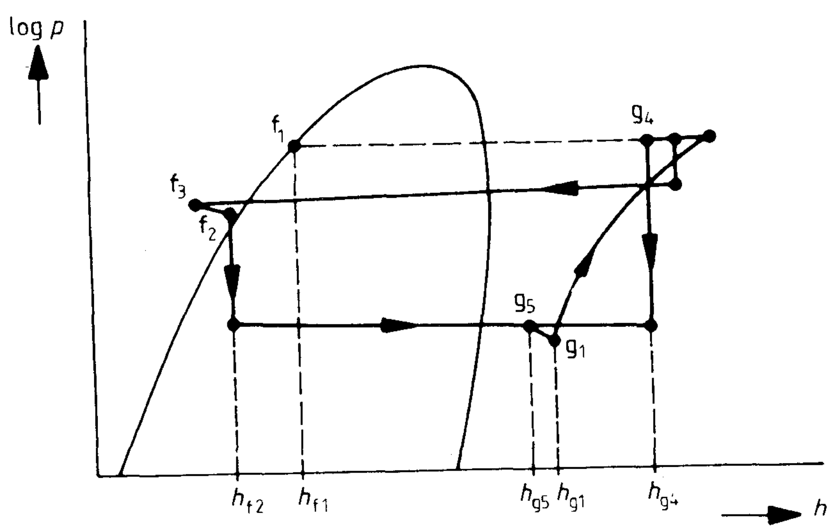


b) Log p versus h diagram

Figure 6 — Method G

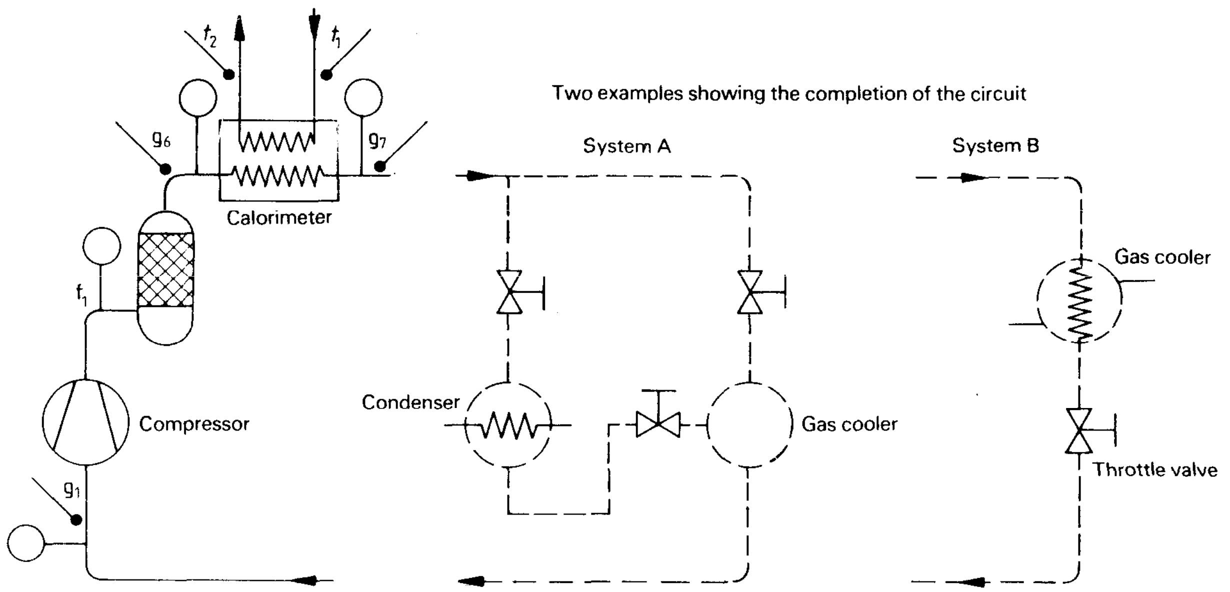


a) Circuit diagram

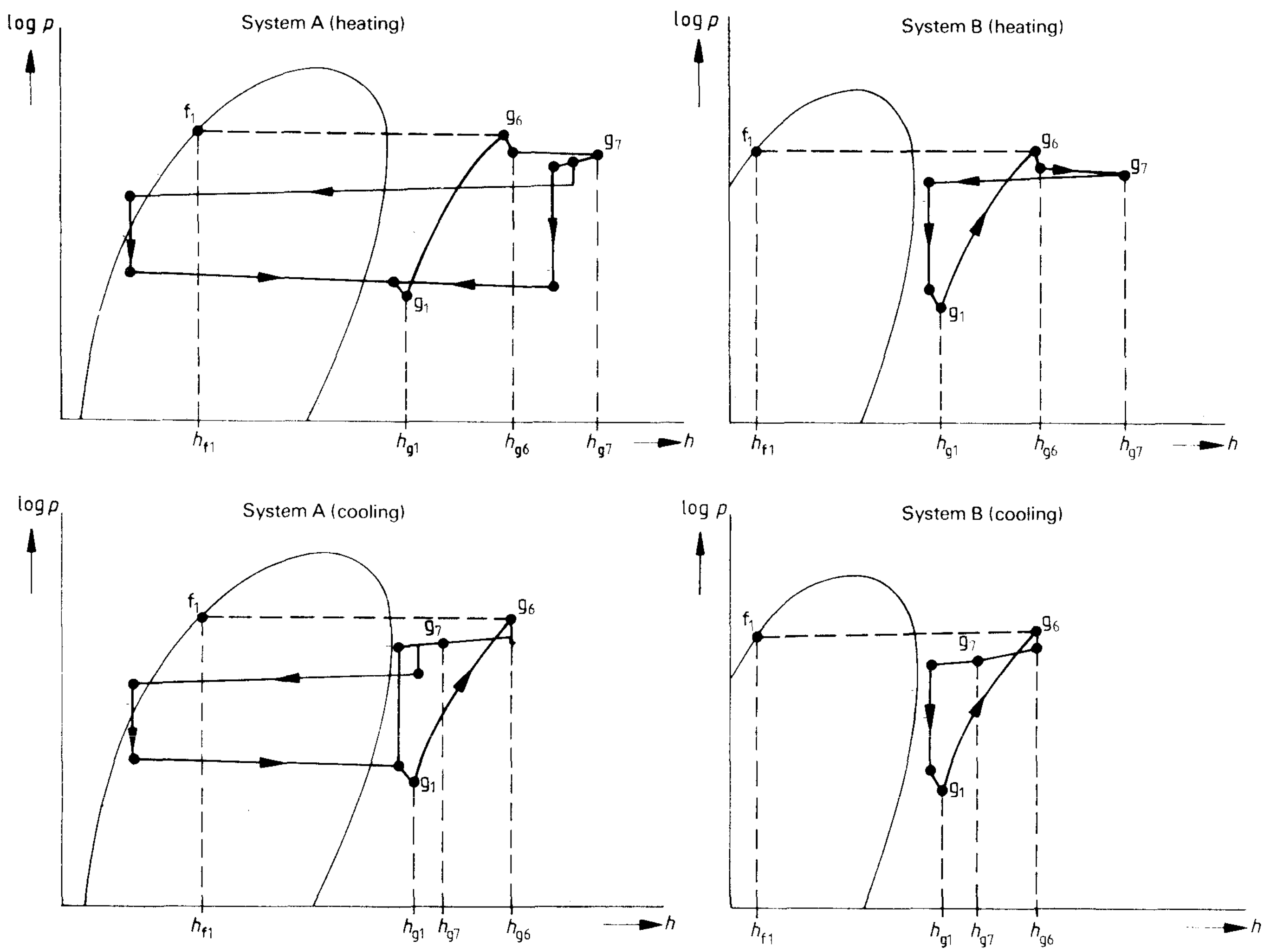


b) Log p versus h diagram

Figure 7 — Method J



a) **Circuit diagrams**



b) **Log p versus h diagrams**

Figure 8 — Method K

Section two : Determination of the power, isentropic efficiency and coefficient of performance

16 General procedure

The calculation of the estimated errors of the power input, the isentropic efficiency and the coefficient of performance is carried out in a similar manner to that for the refrigerant capacity (see C.2).

The provisions of 4.3 and 4.4 apply to section two as appropriate.

The measurements referred to in section two are made simultaneously with those made for determining the refrigerating capacity referred to in section one.

17 Determination of the power input

17.1 Measurement

17.1.1 Direct method

The torque at the compressor shaft may be measured, in certain cases, by means of a suitable device.

The average power shall be calculated from the average torque with an accuracy to ± 2,5 %.

17.1.2 Indirect method

17.1.2.1 A calibrated electric motor of known characteristics is used for the normal power drive. The effective power supplied to the compressor is then obtained from the electrical power input at the motor terminals.

17.1.2.2 If a belt-drive mechanism is used, allowance shall be made for the belt transmission loss.

17.2 Calculation

The power input is calculated from the net torque transmitted and the speed of rotation together with the power absorbed by such ancillaries as are necessary to sustain the operation of the compressor, e.g. an oil pump. When the torque cannot be measured by the direct or the indirect method, the power input measured at the motor terminals shall be recorded.

The actual power input is corrected to the basic test conditions, according to the principles given in 6.6, using the following equation :

$$P = P_a \frac{V_{ga}}{V_{gl}} \frac{n}{n_a}$$

18 Determination of the isentropic efficiency

The isentropic efficiency η_i as defined in 3.4 is calculated using the following basic equation :

$$\eta_i = q_{m_f} (h_{gt} - h_{ga})/P$$

19 Determination of the coefficient of performance

The coefficient of performance ε as defined in 3.5 is calculated using the following equation :

$$\varepsilon = \frac{\Phi_0}{P}$$

Section three : Reporting of results

20 Test report

A test report shall be completed for each test made. The following information shall be given in each test report; the format of presentation is left to the discretion of the user.

General information

Date of the test :

Time test started :

Time test finished :

Duration of test :

Make and serial number of compressor :

Type of compressor (single or double acting, number of cycles, etc.) :

Cylinder diameter and stroke (if applicable) :

Compressor displacement per revolution :

Designation of refrigerant :

Source of thermodynamic properties (tables) used :

Basic test conditions to be specified (see clause 5)

Absolute pressure or saturation temperature at compressor suction :

Temperature at compressor suction :

Absolute pressure or saturation temperature at compressor discharge :

Rotational speed of compressor or details of electrical supply :

Test methods used for

Test X :

Test Y :

Average values of the test readings (see clause 4)

Rotational speed of compressor :

Ambient temperature :

Barometer reading :

Pressure of refrigerant at compressor suction inlet :

Temperature of refrigerant at compressor suction inlet :

Pressure of refrigerant at compressor discharge outlet :

Temperature of refrigerant at compressor discharge outlet :

Inlet temperature of cooling water :

Outlet temperature of cooling water :

Mass flow rate of cooling water :

When possible, compressor lubrication oil temperature :

Voltage and frequency of electrical supply :

NOTES

1) Additional information may be required depending on the test method used (see clauses 8 to 15).

2) The readings referred to above under the heading "Average values of the test readings (see clause 4)" are those taken after calibration.

Results of calculations

Heat leakage factors

Mass flow rate of refrigerant

Relevant enthalpy difference

Refrigerating capacity of compressor

Volumetric efficiency

Power input

Isentropic efficiency

Coefficient of performance

Estimated error of results (see annex C)

Annex A

Types and calibration of measuring instruments and accuracy of measurement

(This annex forms an integral part of the standard.)

The types of measuring instruments used are listed below. Instruments shall be calibrated against certified master instruments before and after each test with the exceptions given in A.4 and A.5.

The accuracy (standard deviation) of a measurement shall be within the limits given in the following clauses except as permitted at A.4 and A.5.

A.1 Temperature measuring instruments

Temperature measurements shall be made with one or more of the following instruments :

a) mercury-in-glass thermometers (the gas flow shall not be appreciably affected owing to the dimensions of the thermometer well);

b) thermocouples;

c) electric resistance thermometers.

The standard deviation of temperature measurements shall be within the following limits :

a) for brine or water in calorimeters, 0,06 °C;

b) for water in condensers, 0,06 °C;

c) for all other temperatures, 0,3 °C.

A.2 Pressure measuring instruments

Pressure measurements shall be made with one or more of the following instruments :

a) mercury column;

b) bourdon tube gauge;

c) diaphragm or bellows gauge.

The standard deviation of pressure measurements shall be within the following limits :

a) for the suction pressure (absolute), 1 %;

b) for other pressures (absolute), 2 %.

A.3 Electrical measuring instruments

Electrical measurements shall be made with one or more of the following instruments :

a) indicating instruments, of either industrial or precision grade as required by the size of the load and as agreed;

b) integrating instruments, of either industrial or precision grade as required by the size of the load and as agreed.

The standard deviation of electrical measurements shall be within the following limits :

a) for power measurements (electrically driven compressors and electrically heated calorimeters), 1 %;

b) for all other electrical measurements, 1 %.

A.4 Refrigerant flow measuring instruments

Flow measurements shall be made with one or more of the following instruments :

a) liquid refrigerant quantity meter, measuring either mass or volume;

b) liquid refrigerant flowmeter;

c) vapour refrigerant flowmeter.

The standard deviation of refrigerant flow measurements shall be as follows :

a) for liquid refrigerant quantity meters and flowmeters, 1 %;

b) for vapour refrigerant flowmeters, 2 %.

Where flow measurement instruments are such that they cannot be readily calibrated, they shall comply with the requirements given in ISO 5167 and the estimated standard deviation in the flow measurement shall be stated in the test report.

A.5 Cooling water flow measuring instruments

Flow measurements shall be made with one or more of the following instruments :

a) liquid quantity meter, measuring either mass or volume;

b) liquid flowmeter.

The standard deviation of cooling water flow measurements shall be ± 1 %.

Where flow measurement instruments are such that they cannot be readily calibrated, an estimate of the uncertainty in the flow rate measurement shall be made in accordance with ISO 5168.

A.6 Speed measuring instruments

Speed measurements shall be made with one or more of the following instruments :

a) revolution counter;

b) tachometer;

c) stroboscope;

d) oscillograph.

The standard deviation of the measurements shall be ± 0,75 %.

A.7 Time measurements

Time measurements shall have a standard deviation of ± 0,1 %, except for the total duration of the test.

A.8 Mass measurements

Mass measurements shall be made to an accuracy of ± 0,2 %.

A.9 Torque measurements

The type of measuring device used should be capable of determining the applied torque with a standard deviation of ± 2,5 %.

Annex B

Symbols used in the text for calculations

(This annex does not form an integral part of the standard.)

Symbol	Definition	International symbol for unit (SI)
A	Area of exposed surface of the condenser	m^2
c	Specific heat capacity of liquid	J/(kg·K)
c_o	Specific heat capacity of oil	
f	Specified electrical frequency	Hz
f_a	Actual electrical frequency	
F_l	Heat leakage factor	W/K
h_{f1}	Specific enthalpy of refrigerant liquid at the temperature of saturation corresponding to compressor discharge pressure specified in the basic test conditions	J/kg
h_{f2}	Specific enthalpy of refrigerant liquid entering expansion valve	
h_{f3}	Specific enthalpy of refrigerant liquid leaving condenser	
h_{ga}	Theoretical specific enthalpy of refrigerant entering the compressor at the specified basic test conditions	
h_{gt}	Theoretical specific enthalpy of refrigerant vapour at compressor discharge pressure having the same entropy as the refrigerant vapour entering the compressor	
h_{g1}	Specific enthalpy of refrigerant entering the compressor at the specified basic test conditions	
h_{g2}	Specific enthalpy of evaporated refrigerant leaving calorimeter or gas cooler	
h_{g3}	Specific enthalpy of refrigerant vapour entering the condenser	
h_{g4}	Specific enthalpy of refrigerant vapour entering gas cooler	
h_{g5}	Specific enthalpy of cooled refrigerant vapour leaving gas cooler	
h_{g6}	Specific enthalpy of refrigerated vapour entering discharge line calorimeter	
h_{g7}	Specific enthalpy of refrigerant vapour leaving discharge line calorimeter	
K	Overall heat transfer coefficient, refrigerant to ambient air at the condenser	W/(m²·K)
n	Specified compressor speed	rev/s
n_a	Actual compressor speed	
P	Power input	W
P_a	Actual power input	
q_{m_c}	Mass flow rate of cooling water	kg/s
q_{m_f}	Mass flow rate of refrigerant, as determined by the test	
q_{m_l}	Mass flow rate of liquid	
q_{m_t}	Total mass flow rate of refrigerant	
q_V	Volume flow rate of liquid refrigerant and oil mixture	m^3/s

Symbol	Definition	International symbol for unit (SI)
t_a	Average ambient temperature	°C
t_c	Average surface temperature of calorimeter	°C
t_d	Mean temperature of surface of condenser exposed to ambient air	°C
t_f	Temperature of saturation corresponding to compressor discharge pressure	°C
t_g	Compressor suction temperature	°C
t_p	Average temperature of saturation corresponding to the pressure of the secondary fluid	°C
t_r	Average temperature of saturation of refrigerant	°C
t_s	Temperature of secondary fluid	°C
t_1	Inlet temperature	°C
t_2	Outlet temperature	°C
V_{ga}	Actual specific volume of refrigerant vapour entering compressor	m^3/kg
$\dot{V}_{gl}$	Specific volume of refrigerant vapour at the suction conditions corresponding to the specified basic test conditions	m^3/kg
V_{sw}	Compressor displacement	m^3/s
x	Oil content of refrigerant-oil mixture, expressed as kilograms of mixture	Dimensionless
ε	Coefficient of performance	Dimensionless
η_i	Isentropic efficiency	Dimensionless
η_V	Volumetric efficiency	Dimensionless
μ	Specific volume of oil	m^3/kg
ϱ	Density of refrigerant corresponding to pressure and temperature at which flow rate is measured	kg/m^3
Φ_h	Electrical input to the heater	W
Φ_i	Heat input to the calorimeter or gas cooler	W
Φ_0	Refrigerating capacity of the compressor	W

Annex C

Estimation of errors

(This annex does not form an integral part of the standard.)

C.1 Estimation of relative error between the results of test X and test Y

C.1.1 As stated in 4.2.4, the results of test X and test Y shall be accepted provided that they correlate within $\pm$ 4 %.

C.1.2 The basis of the calculation is as follows.

The refrigerating capacity of a compressor is determined by two test methods which are carried out simultaneously.

If Φ_{0X} and Φ_{0Y} are respectively the results of the two test methods, 4.2.4 requires that

$$\frac{2\,(\Phi_{0X} - \Phi_{0Y})}{\Phi_{0X} + \Phi_{0Y}} \times 100 < 4$$

C.1.3 The conventional refrigerating capacity Φ_0 (see 3.1) is defined as the product of the mass flow rate q_m and the difference Δh between the specific enthalpy of the refrigerant at the inlet of the compressor, at the test temperature and pressure, and the specific enthalpy of the saturated liquid at the temperature corresponding to the discharge pressure measured during the test, i.e.

$$\Phi_0 = q_m\,\Delta h$$

C.1.4 Since both test methods are carried out simultaneously, the state of the refrigerant at the inlet to the compressor and the state of the refrigerant after condensation in the condenser are the object of a single series of measurements of pressure and temperature and of the same determination from the fluid characteristic diagram.

The measurements of q_m, however, differ, since they are obtained from two separate series of observations, q_{mX} and q_{mY}. Therefore

$$\Phi_{0X} = q_{mX}\,\Delta h$$

and

$$\Phi_{0Y} = q_{mY}\,\Delta h$$

Naturally the estimation of Δh is carried out to a certain degree of approximation depending on the quality of the state reached, the accuracy of the measuring apparatus and the accuracy of the tables of the properties of the refrigerant.

To estimate the degree of agreement between the two measurements of q_m, it can be noted that Δh, whatever the accuracy of its determination, can be eliminated using the formula

$$\frac{2\,(\Phi_{0X} - \Phi_{0Y})}{\Phi_{0X} + \Phi_{0Y}} = \frac{2\,(q_{mX} - q_{mY})\,\Delta h}{(q_{mX} + q_{mY})\,\Delta h} = \frac{2\,(q_{mX} - q_{mY})}{q_{mX} + q_{mY}}$$

The relation given in C.1.2 then becomes

$$\frac{2\,(q_{mX} - q_{mY})}{q_{mX} + q_{mY}} \times 100 < 4$$

C.2 Value of the estimated error in the refrigerating capacity

As specified at 4.4.3 and 4.4.4, at least four readings are taken throughout the test period and the arithmetic mean of the four readings gives the value of the measurement.

NOTE — For quantitative measurements, the difference between the first and last measurement of the test period is taken as the value for the test (see 4.4.5).

C.2.1 Standard deviations

C.2.1.1 General

The standard deviation of each reading or measurement shall not exceed the maximum permitted standard deviation specified in annex A. The estimated error in each reading or measurement shall be taken to be equal to the standard deviation in that reading or measurement under the circumstances of measurement.

The standard deviation in results of calculations based on quantities containing errors shall be calculated using the following rules for the combination of errors.

Let

f be the function to be calculated,

s be the standard deviation in an absolute (not relative) sense, e.g. $a + sa$ means a quantity a with standard deviation sa,

δ be the standard deviation in a relative sense, i.e. $\delta a = \frac{sa}{|a|}$, e.g. for a pressure measurement $a = 10$ bar with a standard deviation $sa = 0{,}2$ bar,

$$\delta a = \frac{0{,}2}{10} = 0{,}02 \text{ or } 2\ \%$$

and

sf be the standard deviation in the function f

In general

$$sf = \sqrt{\sum_{i=1}^{n}\left(\frac{\delta f}{\delta x_i} \times sx_i\right)^2}$$

where

n is the total number of readings (or measurements) taken;

x_i is the value of the i^{th} reading (or measurement) x.

For special cases of the function f, the standard deviation in the function is as follows.

a) $f = a + b + c$

$$sf = \sqrt{(sa)^2 + (sb)^2 + (sc)^2}$$

b) $f = a \cdot b \cdot c$

$$\delta f = \sqrt{(\delta a)^2 + (\delta b)^2 + (\delta c)^2}$$

c) $f = \frac{a}{b}$

$$\delta f = \sqrt{(\delta a)^2 + (\delta b)^2}$$

d) $f = a^p$

$$\delta f = \sqrt{(p \cdot \delta a)^2} = p \cdot \delta a$$

e) $f = a^{1/q}$

$$\delta f = \frac{1}{q}\,\delta a$$

C.2.1.2 From thermodynamics diagrams

In a log p versus h diagram for a refrigerant, the enthalpy is represented graphically as a function of two other quantities, most commonly the pressure p and the temperature T.

If the standard deviations in p and T are sp and sT respectively, the standard deviation in the enthalpy, sh, can be found graphically as follows (see figure 9).

The abscissa of the point of intersection of the isotherm T and the isobar p is the enthalpy h.

Draw lines $T + sT$ and $T - sT$ parallel with the isotherm T.

Draw lines $p + sp$ and $p - sp$ parallel with the isobar p. A diamond-shaped area is thus formed, bounded by the lines $T + sT$, $T - sT$, $p + sp$ and $p - sp$. Provided that the lines are drawn with sufficient accuracy, the width, 2 sh, along the h axis of the diamond-shaped area thus formed gives the standard deviation sh in the enthalpy.

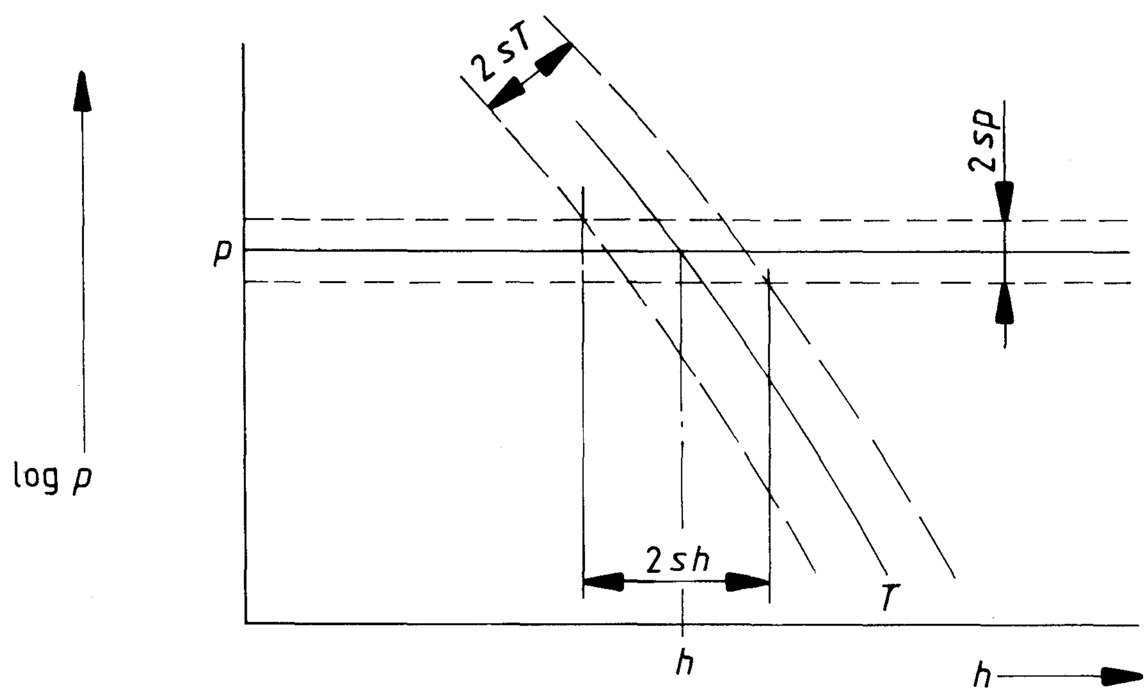


Figure 9 — Log p versus h diagram

Usually sT and sp are so small that it is not practicable to draw the lines $T \pm sT$ and $p \pm sp$. Therefore the graphical determination of sh is carried out using an enlarged scale, e.g. by taking 10 sT and 10 sp which then yields the value of 20 sh.

C.2.2 Calculation of the estimated error

When all readings have been taken and each resulting value of the measurement has been reported, the mass flow rate and hence the refrigerating capacity may both be calculated.

As specified at 4.2.2, it is necessary to calculate the value of the estimated error in the refrigerating capacity.

This calculation may have to be made in two stages as follows : first, to determine the estimated error in each of the relevant terms of the equation (or equations) for the mass flow rate or refrigerating capacity and, second, to determine the estimated errors in the values of the mass flow rate itself and the refrigerating capacity itself, all errors being expressed in terms of standard deviations.

The calculations given in the following example will be required to give the standard deviation for the results of both test methods (see 4.2.5).

Example of calculation of the estimated error for method G

The values of the measurements are used to determine the value of the mass flow rate (see 13.5.1) given by

$$q_{m_f} = \frac{c\,(t_2 - t_1)\,q_{m_c} + F_l\,(t_r - t_a)}{h_{g3} - h_{f3}}$$

and the refrigerating capacity (see 13.5.2) given by

$$\Phi_0 = q_{m_f} \frac{V_{ga}}{V_{gl}} (h_{g1} - h_{f1})$$

The types of error to be considered in this example are

a) the temperature difference, $t_2 - t_1$;

b) the flow rate of cooling liquid, q_{m_c};

c) the enthalpy differences, $h_{g3} - h_{f3}$ and $h_{g1} - h_{f1}$.

The standard deviations in each reading or measurement are assumed to be equal to the maximum allowed standard deviations specified in annex A.

Stage one

The estimated error in each of the relevant terms of the equations is calculated as follows.

a) From annex A, the standard deviation in the measurement of brine or water temperatures is assumed to be 0,06 °C. The measured value of $t_2 - t_1$ is assumed to be 6 °C.

The standard deviation in $t_2 - t_1$ is calculated, in accordance with C.2.2, as follows :

$$s\,(t_2 - t_1) = \sqrt{(0{,}06)^2 + (0{,}06)^2} = 0{,}085$$

$$\delta\,(t_2 - t_1) = \frac{0{,}085}{6} = 0{,}0141 \text{ or } 1{,}41\ \%$$

b) From annex A, the standard deviation q_{m_c} in the cooling water flow measurement shall not exceed 1 %.

c) The standard deviations in $h_{g1} - h_{f1}$ and in $h_{g3} - h_{f3}$ depend on the standard deviations in the pressure and temperature measurements (and on any error in the tables).

From annex A, the standard deviation in the pressure measurements shall be ± 2 % and that in the temperature measurements shall be ± 0,3 °C.

The four standard deviations sh in the enthalpy values h_{g1}, h_{f1}, h_{g3} and h_{f3} may be determined from figure 6.

Alternatively, these four standard deviations sh depend on the four standard deviations sp in the four corresponding pressures p_{g1}, p_{f1}, p_{g3}, p_{f3} and on the three standard deviations st in the three corresponding temperatures t_{g1}, t_{g3} and t_{f3}, the temperature at point f_1 being regarded as correct as this point is on the saturated liquid line. (The standard deviations at points g_1 and f_1 are indicated in figure 10.) They are therefore calculated according to the method described in C.2.1.2.

Once the four standard deviations sh in the four enthalpy values have been calculated, the standard deviations in $h_{g1} - h_{f1}$ and in $h_{g3} - h_{f3}$ may be determined in a similar manner to that employed in a) above.

Therefore

$$s\,(h_{g1} - h_{f1}) = \sqrt{(sh_{g1})^2 + (sh_{f1})^2}$$

and

$$s\,(h_{g3} - h_{f3}) = \sqrt{(sh_{g3})^2 + (sh_{f3})^2}$$

In this example, these standard deviations are both taken to be 0,01 or 1 %.

Stage two

The standard deviations calculated in stage one for

a) the temperature difference, $\delta\,(t_2 - t_1) = 1{,}41\ \%$,

b) the flow rate of cooling liquid, $sq_{m_c} = 1\ \%$, and

c) the enthalpy difference, $s\,(h_{g3} - h_{f3}) = 1\ \%$

[the error in $h_{g1} - h_{f1}$ may be similarly taken as 1 % (see figure 4)] are then used to determine the total standard deviations.

The total standard deviation in the mass flow rate is thus

$$\sqrt{1{,}41^2 + 1^2 + 1^2} = 2\ \%$$

The total error in the refrigerating capacity is therefore

$$\sqrt{2^2 + 1^2} = 2{,}23\ \%$$

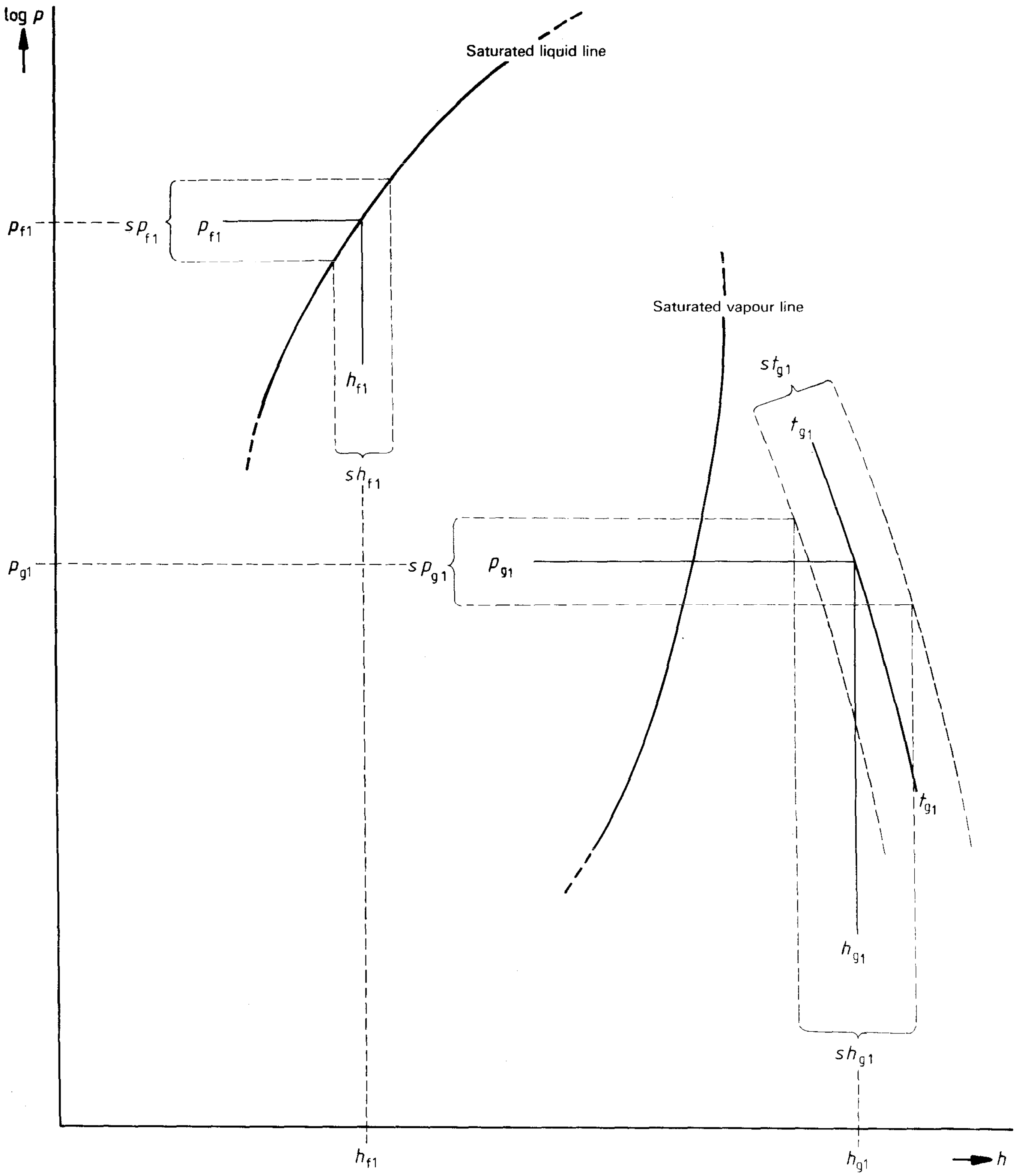


Figure 10 — Example showing the determination of the errcrs in the enthalpy values for method G (see figure 6)

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(Continued from second cover)

The text of ISO standard has been approved for publication as Indian Standard without deviations. Certain terminology and conventions are however not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use point (.) as the decimal marker.

In this adopted standard, reference appears to an International Standard for which Indian Standard also exists. The corresponding Indian Standard which is to be substituted in its place is listed below along with the degree of equivalence:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 5167	IS 4477 (Part 1) : 1967 Methods of measurement of fluid flow by means of venturi meters: Part 1 Liquids	Technically equivalent

The technical committee responsible for the preparation of this standard has reviewed the provisions of the ISO standards ISO 916-1, ISO 1662 and ISO 5168 and decided that they are acceptable for use in conjuncton with this standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Handbook and 'Standards Monthly Additions'. Comments on this Indian Standard may be sent to BIS giving the following reference:

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